

## Using Hydroacoustic Technology to Detect and Track Ultrasonic Tagged Fish: Methodology and Preliminary Results

Draft Project Summary Report  
October 22, 2007

Prepared by Scott W. Milne

## Table of Contents

Introduction .....	3
Methods: .....	4
Survey Vessel and Transducer Set-Up.....	4
Hydroacoustic Systems .....	5
Lake Trout Tags and Hydrophone Receiver .....	7
Lake Trout Netting & Surgeries.....	8
Tracking.....	12
Lotek MAP Tag Detection Calibration.....	12
Multi-frequency Crepuscular Survey.....	12
710 kHz Acoustic Backscatter & Zooplankton Net-haul Density .....	13
Hydroacoustic Transducer Calibrations .....	14
Habitat Mapping.....	15
Preliminary Results .....	16
Tag Detection Trials – Lotek “Maphost” Hydrophone Software .....	16
Tag Detection Trials – SM20 Multi-beam Hydroacoustics .....	17
Fish Tracking .....	18
In Situ Target Strength Estimates .....	22
Lake Trout Movement.....	22
Lake Trout Interactions and Foraging Behaviour .....	24
Habitat Mapping.....	24
Field Challenges and Future Considerations .....	28
Appendices .....	30



**Milne Technologies**

*Environmental & Aquatic Resource Consulting*  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)



# Milne Technologies

*Environmental and Aquatic Resource Consulting*

**[www.milnetechnologies.ca](http://www.milnetechnologies.ca)**

28 Bradley Blvd. RR1 Hampton Ontario Canada L0B 1J0

Tel: (416) 848-3948 [info@milnetechnologies.ca](mailto:info@milnetechnologies.ca)

Please contact Milne Technologies for the complete report.

## ***Introduction***

The purpose of the study is to describe a method for directly measuring the *in situ* target strength of lake trout (*salvelinus namaycush*) using integrated multi-beam, split-beam and biotelemetry technologies. Pulse coded ultrasonic tags engineered to ping at 200 kHz were surgically implanted into lake trout and released. The study area within Lake Opeongo was surveyed over a two week period with an SM20 multi-beam sonar and an EK60 multi-frequency echosounder system in an effort to locate and track tagged fish. Data recorded included target strength measurements, habitat information, and information about other “trout like” targets and lake herring schools. This work also provides a unique opportunity to describe the spatial distribution and behavioural patterns of lake trout as they relate to the schooling behaviour of their prey or to other individuals.

Additional work was also completed over the survey period to expand on previous studies focused on developing methods for generating zooplankton density and biomass estimates from 710 kHz single beam hydroacoustics.

This work was only made possible with technical & financial support provided by the project collaborators:

Mark Ridgway	OMNR & Harkness Lab– Peterborough, Canada
Trevor Middel	OMNR & Harkness Lab– Peterborough, Canada
Brian Shuter	OMNR & University of Toronto, Ontario Canada
Jeff Condiotty	Mesotech /Kongsberg Simrad, Inc., Washington, USA
Ian Higginbottom	SonarData Pty Ltd., Hobart, Australia.
Gary Sprules	University of Toronto at Mississauga, Mississauga, Canada
Robert Keetch	Upper Great Lakes Mgmt. Unit, OMNR, Owen Sound, Canada

The purpose of this document is to provide a description of the field activities, methods, and preliminary results from the Lake Opeongo Integrated Multi-frequency Hydroacoustic and Biotelemetry Surveys completed June 19 – July 17, 2007.



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

## **Methods:**

### **Survey Vessel and Transducer Set-Up**

All acoustic surveying and lake trout tracking was completed using the Harkness Lab research vessel “Henley” (figure 1a). A considerable amount of time was required to retro-fit the vessel to accommodate the various computers, processing units, power requirements, and transducer mounts. A custom computer rack, shelving, generator mount and weather proof top was constructed with assistance from OMNR staff. Custom aluminum transducer mounts were used to deploy the SM20 imaging & profiling head at the forward port side and the EK60 split- or single beam multi-frequency array on the forward starboard. The transducer mount assembly consisted of two aluminum tubes fixed to a square aluminum cross piece that extended across the vessel beam and bolted to the gunwales (figure 1b). The depth of the transducers could be adjusted by sliding the aluminum poles through the tube sheaths welded to the square cross piece. The transducer mount was designed by Milne Technologies and assembly was completed by Truway Machine Manufacturing Ltd of Combermere. Design prints of the transducer mounts are available in Appendix 1.



Figure 1a & b: Acoustic survey vessel “Henley” outfitted with split- beam and multi-beam hydroacoustic systems. The transducers were deployed off of aluminum poles on the forward port and starboard gunwales. A reinforced cross-beam with aluminum tubes were welded on each end to allow the depth of the transducers to be adjusted.



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

## Hydroacoustic Systems

*Simrad SM20* – This was the primary system used to detect and track the tagged lake trout. The multi-beam transducer imaging head consists of 128 independent single  $1.5^\circ \times 20^\circ$  beams at 200 kHz that are positioned approximately  $1^\circ$  apart (figure 2a). The acoustic signals from all the beams are processed within the surface unit to produce a single image of a  $120^\circ$  swath through the water column for each ping. The ping rate was observed to be between 4 – 2 times per second. Acoustic signals produced by the Lotek tags are easily detected by the SM20 array and appear on the multi-beam display in real-time as a strong backscatter “flash” within the beam the target was detected (figure 2b). The observed position of the observed target within the beam allowed the vessel operator the ability to move the vessel (in the athwartship plane) over the target.

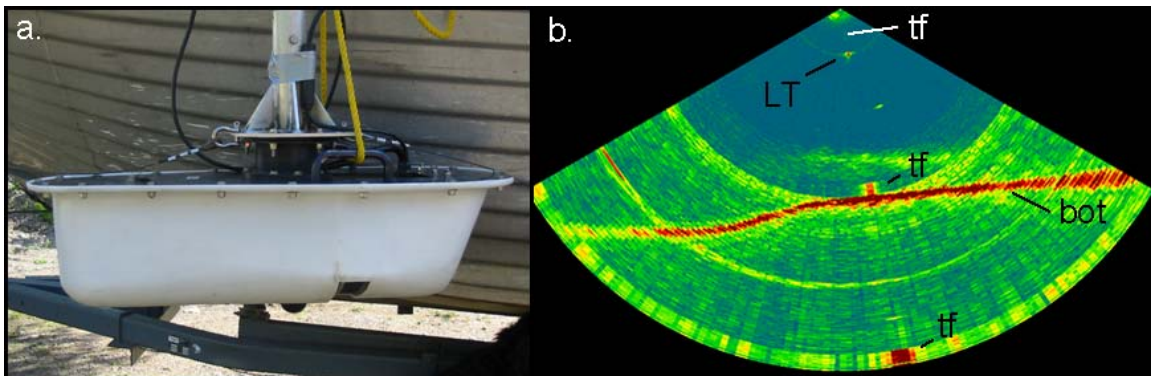


Figure 2a & b: a. The Simrad SM20 multi-beam transducer deployed off the forward port side of the survey vessel. The imaging and profiling heads are hidden within the protective white cowling. b. Image of the SM20 echogram. Shown is the tagged lake trout “LT” (Tag ID 3) suspended at 9.7 m over the lake bottom (“bot”) at 39.2 m. Note the tag flashes (“tf”) extending below and above the target within one of the beams.

*Simrad EK60* – After steering the survey vessel over the tagged trout, we used a split-beam hydroacoustic system to record the acoustic backscatter and target strength of the tagged trout. For surveys completed between July 4 and July 9, TS measurements were obtained using an elliptical 120 kHz  $4.4^\circ \times 9.0^\circ$  transducer. All remaining surveys (July 10 – 17) also included measurements from a 70 kHz  $11^\circ \times 11^\circ$  transducer. We completed a crepuscular survey of the main basin of the South Arm on the evening of July 13 that included the 70 and 120 kHz transducer as well as a 200 kHz  $7^\circ \times 7^\circ$  and a 710 kHz  $5^\circ \times 5^\circ$  system (figure 3). Additional work was completed by fisheries technician Rob Keetch in an effort to calibrate the 710 kHz backscatter with Clarke-Bumpus zooplankton samples. Transducer settings and specifications are summarized in table 1.



Table 1: Specifications (i), environmental (ii), and calibration (iii) parameters for the 70, 120, 200, and 710 kHz EK60 multi-frequency hydroacoustic array used during the 2007 Lake Opeongo surveys.

<b>i. Transducer Description</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Nominal frequency, kHz	70	120	200	710
Transducer type	Simrad ES70-11	Simrad ES120-7G	Simrad ES200-7C	Simrad 710-30
Beam type	Split	Ellip. Split	Split	Single
GPT Ser. Num.	009072058116-2	0090720112d4-1	009072010fd0-3	009072016db6-4
Transmit power (W)	800	500	300	100
Pulse duration (µs)	128	128	128	128
Sample Interval (µs)	32(23)	32(23)	32(23)	32(23)
Band width (kHz)	6.815	10.923	15.73	2.3611
2-way beam angle (dB):	-16.8	-21.5	-20.7	-23
Noise estimate (dB)	<-110	<-110	<-110	<-110
Angle Sens. - along. (°)	13	36	23	0
Angle Sens. - athwart. (°)	13	18	23	0
3dB Beam Width - along (°)	11	4.4	7	5.4
3dB Beam Width - athwart (°)	11	9	7	5.4
<b>ii. Environmental Variables</b>				
Water temperature (°C)	12	12	12	12
Salinity (ppt)	0	0	0	0
Sound speed (m/s)	1455	1455	1455	1455
Est. absorption (dB/km)	1.4	4.11	11.42	143.88
<b>iii. Calibration</b>				
Tungsten carbide calibration				
sphere diameter (mm)	38.1	38.1	38.1	
Theoretical TS of sphere (dB)	-40.65	-39.75	-39.48	
Gain (dB)	17.375	25.41	26.05	27.5
Sa correction (dB)	-0.18	-0.76	-0.71	0





Figure 3: Image of the Simrad split-beam transducers mounted on an aluminum plate. The transducer array was deployed ~50 cm below the surface on the forward starboard gunwale of the survey vessel. Transducers shown are; forward left – 120 kHz (4.4° X 9.0°), rear left - 70 kHz 11° X 11°, forward right - 200 kHz 7° X 7°, and rear right - 120 kHz 7° X 7°. Not shown is the 710 kHz 5°X5° transducer.

## Lake Trout Tags and Hydrophone Receiver

The 200 kHz ultrasonic tags were engineered and assembled by Lotek Wireless Inc. 18 tags were purchased by OMNR and the hydrophone receiver hardware, required to identify the tag code, was leased from the manufacturer for the duration of the project. Detailed descriptions of the tags and hydrophone receiver hardware are available in table 2a & 2b. Lotek also provided a customized foam baffle to fit around the hydrophone receiver. The purpose of the baffle was to exclude tag signals from being detected along the rear side of the hydrophone thus making the omni-directional hydrophone somewhat semi-directional. The forward facing hydrophone was submerged and mounted on the gunwale facing below the SM20 transducer on the aft-port side. The face of the transducer was angled at a ~45° angle from vertical to optimize tag detection below the transducer array and for searching in front of the survey vessel (figure 4).



Table 2a: Technical specifications of (a.) the Lotek 200 kHz tags and (b.) the Lotek hydrophone receiver & MapHost software used in this study. Additional information is available from Lotek's web site ([www.lotek.com](http://www.lotek.com)).

a. Lotek Wireless MAP Tags	b. Lotek Acoustic Receiver
Model Number: MA11-18	Model Number: MAP 600 RT-P1
MAP Acoustic Transmitter – 200 KHz	MAP Acoustic Receiver – Single Port - 200 KHz
Size: 11 mm diam.; 48 mm length;	Laptop to run "MapHost" data logging software.
Wght in air = 8.9 g, Wght in water = 4.2 g	Omni-directional Hydrophone with Baffle
Warr. Life: 47 days at 2.5 sec. burst rate	Purchase Price:
Purchase Price:	Lease Price (2 months):

## Lake Trout Netting & Surgeries

All lake trout tagging was completed between June 19 – 22, 2007. We used short duration (avg. 1hr 27min., std. dev. 7 min) gill nets set at suspected lake trout locations within the South Arm to live capture lake trout for tagging (table 3). Monofilament, mixed mesh gill nets (6 panels, 2.2 m height, 1.5" & 2.0" mesh) were set where bottom depths varied between 7 and 22 m (avg. 14.6 m, std. dev. 2.1m).

On retrieval of each net, lake trout of suitable size were carefully removed from the meshes and placed into a large covered cooler of water that was cooled to ~10°C with bottled ice. Prior to surgery, we anaesthetized each fish in a bath of ethanol and clove oil (in a ratio of 9:1) and 20 L of fresh water. During the surgery, a mild clove oil and water solution was pumped over the gills to prevent tissue drying. The tag was inserted into a small incision and stainless steel surgical staples were used to close the wound (figure 5). The tagged fish was then monitored in a recovery bath of cool water and released over deep water near the netting site.

Of the 18 tags procured, 16 were successfully implanted into lake trout and released. The length and weight of lake trout captured, tagged and released ranged from 412 mm to 848 mm (avg. 533 mm, std. dev. 111 mm) and 845 g to 8620 g (avg. 2141 g, std. dev. 1892 g) respectively (table 4).



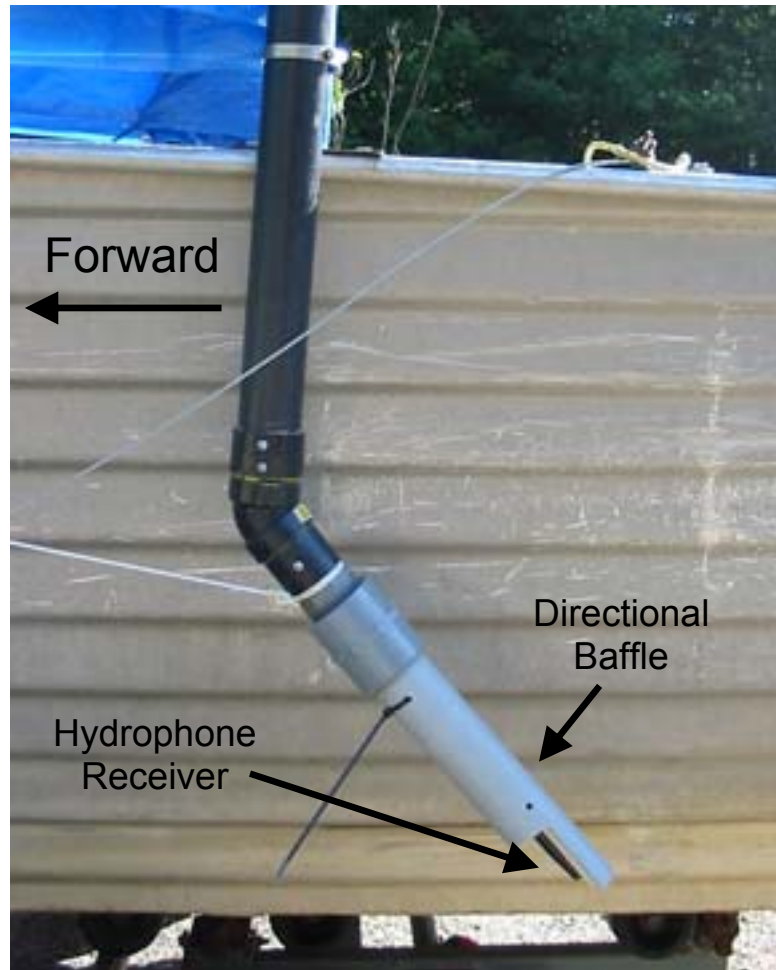


Figure 4: Image of the Lotek hydrophone receiver mounted on the port side gunwale of the survey vessel.

Table 3: Summary of the netting sites, effort, and GPS coordinates.

Sam Num	Site Name	Date	Time Set	Time Fished	Depth Min (m)	Depth Max (m)	Easting	Northing	Proj.	UTM Zone
1	Humps	20070621	11:20	12:47	18	20	704284	5063139	NAD83	17
2	Sunnyside	20070621	12:09	13:47	11	14	704859	5063875	NAD83	17
3	Froggers Pt.	20070621	13:15	14:34	10	17	705790	5063160	NAD83	17
4	Windy Pt.	20070621	19:50		12	18	704253	5062024	NAD83	17
5	Englehart Isld.	20070621	20:35		7	22	705188	5061381	NAD83	17
6	Finger Isld.	20070622	09:03	10:21	13	18	701872	5063818	NAD83	17
7	Weather Stn. Isld.	20070622	09:41	11:11	10	16	702805	5063557	NAD83	17
8	Sunnyside	20070622	11:52	13:23	10	15	704866	5063849	NAD83	17
9	Froggers Pt.	20070622	12:30	13:56	12	20	705921	5063346	NAD83	17



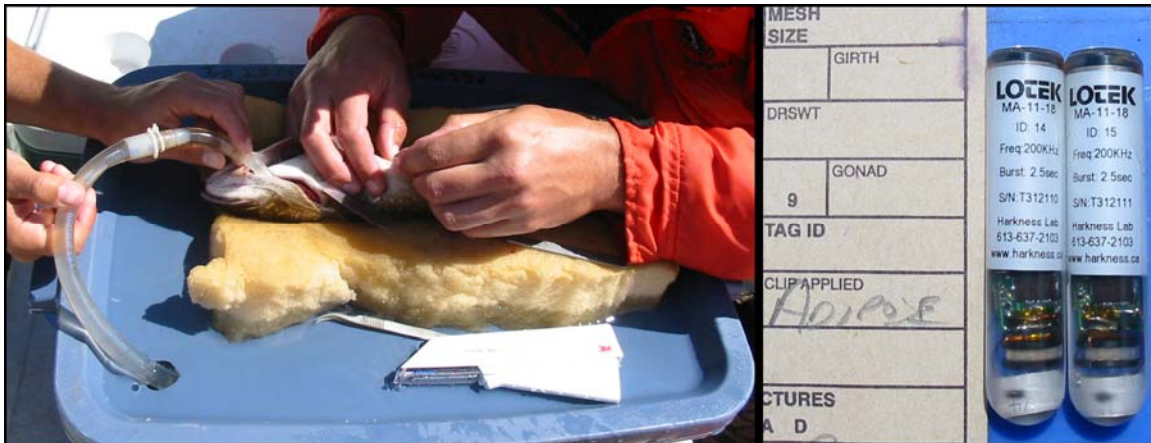


Figure 5: A mild solution of water, clove oil and ethanol was pumped over the gills of the lake trout during the surgery procedure (left). The tag (right) was inserted into the abdomen at the point of extension of the pectoral fins. Stainless steel surgical staples were used to close the incision.



Table 4: Summary of the lake trout biological sampling and tagging information.

Sam. Num.	Fish Num.	Fork Len. (mm)	Total Len. (mm)	Rnd. Wght (g)	Sex	200 kHz Tag ID	T-Tag Applied	PIT Tag Applied	Clip Applied	Comments
2	1	501	550	1450	1	1	C9501			
2	2	699	756	3760	2	2	C9502			
3	1	483	534	1400	2	3	C9503			
3	2	542	596	2100	1	4	C9504			
3	3	486	537	1400	2	5	C9505			
4	1	848	895	8620	UK	6	C9506	145553557A		Dble T-Tag Applied C9507
4	2	448	499	1065	UK	7	C9508	136173256A		
4	3	484	536	1475	UK	8	C9509	135728746A		
6	1	596	650	2480	UK	9	C9510	145659492A	A	
6	2	616	670	2845	UK	10	C9511	145555453A	A	
7	1	494	539	1256	UK	11	C9512		A	No PITs Applied
8	1	462	504	1140	UK	12	C9513		A	No PITs Applied
8	2	430	473	915	UK	13	C9514		A	No PITs Applied
8	3	412	455	845	UK	14	C9515		A	No PITs Applied
9	1	538	588	1860	UK	15	C9516			Recap. PIT 136175177A
9	2	494	540	1650	UK	16	C9517			No PITs Applied
<i>Average</i>		533	583	2141						
<i>Std. Dev.</i>		111	113	1892						



## Tracking

Lake trout tracking occurred July 4 – 17 and was limited to the South Arm basin. Typically, the survey crew would begin searching for tagged lake trout in a clockwise or counter clockwise direction around the basin following the 12 to 22 m contour until either a flash was observed on the SM20 display or a strong (>80) tag pulse was recorded by the Lotek hydrophone receiver. When a tagged fish was detected, the crew attempted to steer the survey vessel in the direction that maximized the tag signal while viewing the SM20 multi-beam display for tag “flashes”. Once the target was observed on the multi-beam, the vessel was maneuvered to capture the target within the much narrower 70 kHz and/or 120 kHz split-beam array.

## Lotek MAP Tag Detection Calibration

As an attempt to determine the detectability of the Lotek tags with the SM20 multi-beam and hydrophone receiver, we completed a series of short transects around a known tag location with all sensors running. The tag was covered in a single layer of duct tape and attached to a rope that stretched between a buoy and anchor and suspended off bottom at approximately 17.5 m deep. The bottom depth of the site was ~27.3 m. The tag detection trials were completed on July 6, 2007 11:15:00 – 11:57:00.

## Multi-frequency Crepuscular Survey

A crepuscular multi-frequency hydroacoustic and optical plankton counter (OPC) survey was completed during the crepuscular period on the evening of July 13, 2007. The survey followed a similar transect path to the OMNR Harkness Lab South Arm survey route and followed a zig-zag pattern across the main basin (figure 6). Hydroacoustic data were recorded from all available EK60 frequencies (70, 120, 200, and 710 kHz) and include SM20 multi-beam data on alternating transects (figure 6).



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

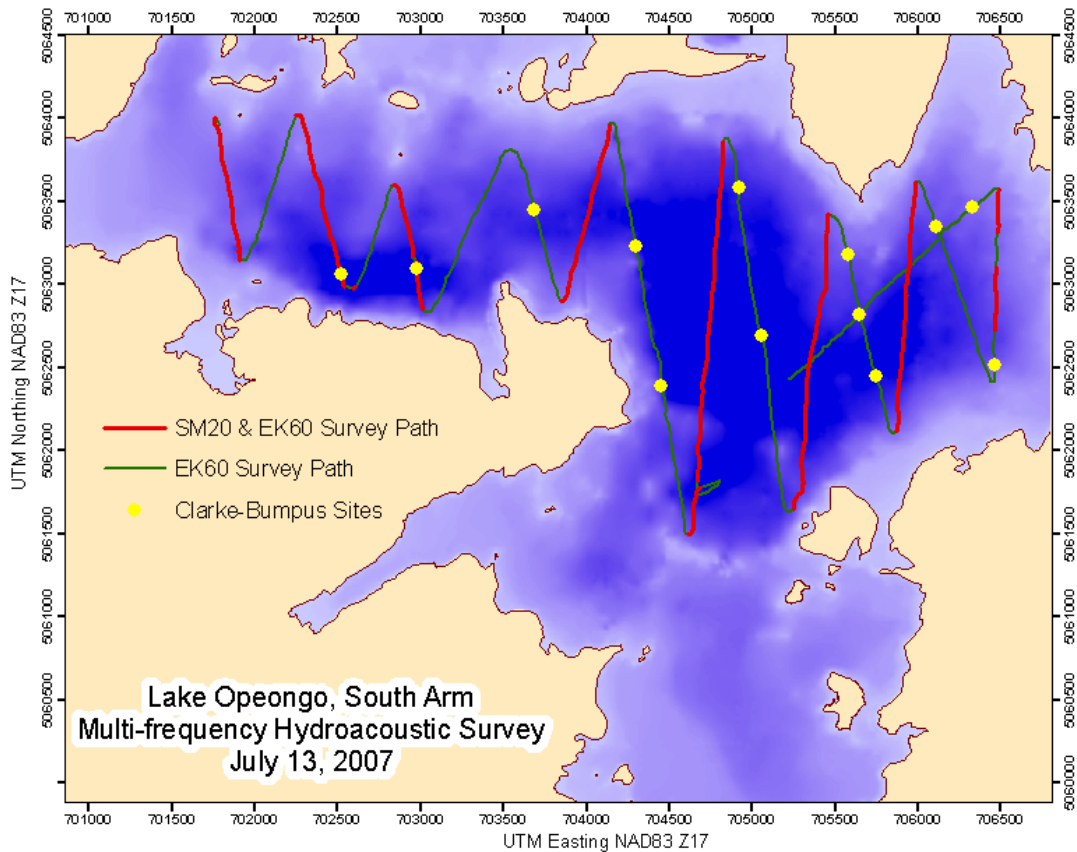


Figure 6: Vessel track from the July 13, 2007 multi-frequency hydroacoustic survey of the South Arm main basin. Shown are the survey transects where EK60 (—) or EK60 & SM20 (---) data are available. Light circles indicate Clarke-Bumpus zooplankton sample sites.

We used a second vessel, operated by Dr. Gary Sprules, to deploy the OPC. “Abeunga” followed alongside the acoustic survey vessel “Henley” to simultaneously collect zooplankton size and density data at the depth of the OPC. The OPC was affixed to a pole mount attached to the gunwale and was submerged ~2m below the surface. Data analysis is expected to follow closely the methods described in the February 7, 2007 “OLLT\_710kHz\_Acoustic\_Methodology” prepared by Milne Technologies.

## 710 kHz Acoustic Backscatter & Zooplankton Net-haul Density

Further calibration of the EK60 - 710 kHz split beam as an effort to determine zooplankton density was completed on July 13 and July 17 in collaboration with fisheries technician Rob Keetch. During the July 13 multi-frequency survey, we used a Clarke-Bumpus closing plankton net to collect zooplankton samples from 13 sites distributed across the main basin of the South Arm. At each station the survey vessel was slowed to ~4.0 km/h and the Clarke-Bumpus was towed for 2



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

minutes. The net was then lifted, rinsed, and the sample was preserved in ethanol. A summary of the plankton sampling sites is available in table 5.

Table 5: Summary of the Clarke-Bumpus zooplankton netting sites sampled during the July 13, 2007 multi-frequency hydroacoustic survey on Lake Opeongo

Sample	Date	Time	Easting	Northing	UTM Zone
1	20070713	20:02:00	702520	5063062	17T
2	20070713	20:23:58	702979.3	5063097	17T
3	20070713	20:41:02	703679.8	5063447	17T
4	20070713	21:05:31	704294.1	5063235	17T
5	20070713	21:14:27	704450.2	5062388	17T
6	20070713	22:09:22	704918	5063589	17T
7	20070713	22:19:30	705059.1	5062690	17T
8	20070713	22:49:33	705579.2	5063183	17T
9	20070713	22:57:16	705743.7	5062451	17T
10	20070713	23:18:25	706109.5	5063354	17T
11	20070713	23:29:32	706462.8	5062518	17T
12	20070713	23:42:06	706329.6	5063466	17T
13	20070713	23:53:14	705641.9	5062819	17T

## Hydroacoustic Transducer Calibrations

Calibration of all split-beam transducers was completed on July 12 with assistance from Ian Higginbottom of Sonardata and Trevor Middel of OMNR. We used the Echoview Echolog and ER60 calibration software to map the beams of the 70 kHz ( $11^\circ \times 11^\circ$ ), 120 kHz ( $4.4^\circ \times 9.0^\circ$ ) and 200 kHz ( $7^\circ \times 7^\circ$ ). A tungsten carbide (6% cobalt binder) calibration sphere (~38.1 mm diameter) was suspended on a monofilament fishing line ~2.75m above a lead weight. The calibration sphere was lowered below the transducers to 6.9 m, 14.8 m, and 18.9 m. At each depth we varied the pitch & roll of the boat and also used a second monofilament strand attached to the sphere from a fishing rod to move the calibration sphere through the beams.

The virtual variable module within Echoview (EV) was used to calculate the TS gain and  $S_a$  correction parameters for three frequencies. The calibration parameter results were updated to all EV tracking and multi-frequency survey projects. Details of the calibration exercise are available in Appendix II.

The 710 kHz transducer was not calibrated during this project. Information provided by Simrad indicates the 710 kHz transducer and GPT were calibrated just previous to these surveys.

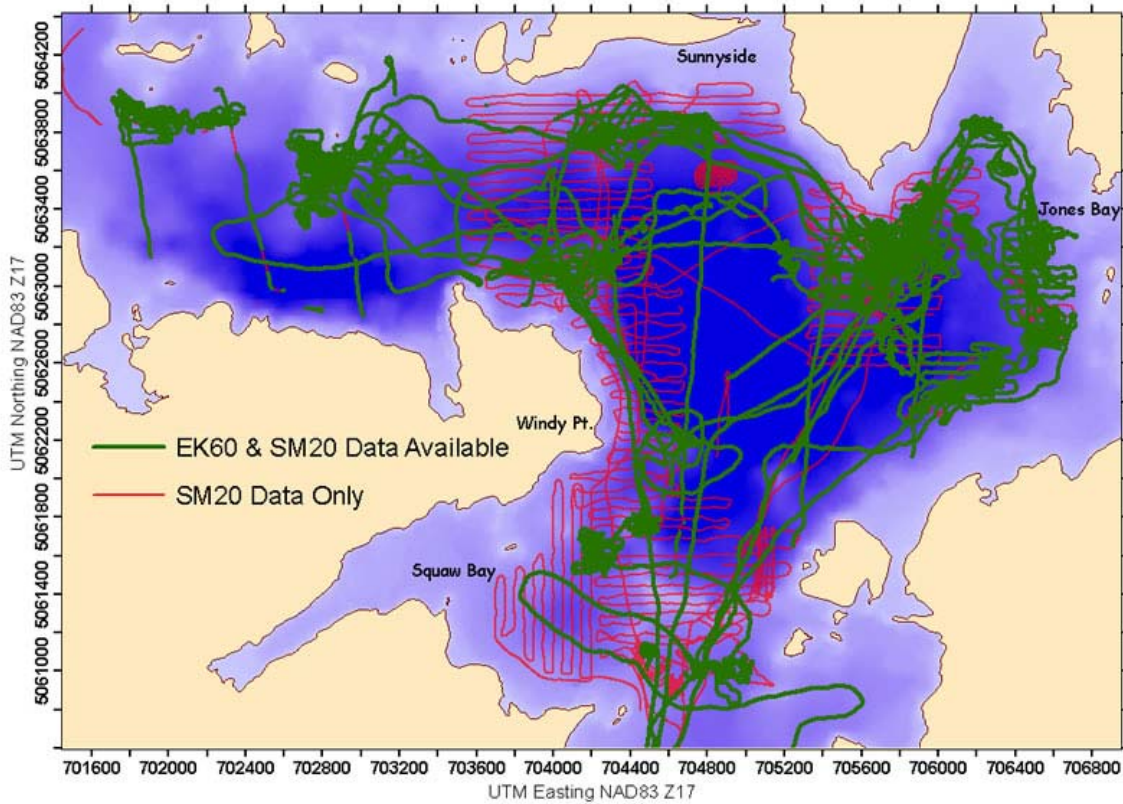


**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

## Habitat Mapping

Intensive multi-beam swath and split-beam lakebed mapping of key lake trout habitat was completed July 2-3 with additional areas mapped opportunistically throughout the entire survey (figure 6).



Lake Opeongo, South Arm - Lake Bottom & Habitat Mapping Data Availability

Figure 6: Vessel tracks where lake bottom and habitat mapping information was collected. Shown are the survey vessel tracks where EK60 (——) or EK60 & SM20 (-----) data are available.



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

## **Preliminary Results**

### **Tag Detection Trials – Lotek “Maphost” Hydrophone Software**

Results of the tag detection trials indicate that the tag “power” reported from the Lotek Maphost hydrophone receiver software provides a relative measure of the distance of the tagged fish from the survey vessel (figure 7). The test tag (Tag ID 17) signal power varied from a minimum value of “5” at 111 m away from the tag to “112” at 4.5 m away. The maximum distance from which the tag was detected with the hydrophone was 189 m. The mean distance from the tag where tag power was  $\geq$  “90” was ~30 m with a maximum distance of 71 m (table 5). Note that on average, the greatest tag power was observed at a point ~40 m from ahead of the tag position, decreasing as the vessel moved over the tag, and was followed by a rapid decrease in tag strength as the vessel moved past the tag location (figure 8). This likely demonstrates the effect of the directional baffle applied to the hydrophone as well as the forward facing deployment angle of the hydrophone mount (figure 4).

Table 5: Summary of the detectability of the Lotek MAP 200 kHz tags by the Lotek Maphost hydrophone hardware and the Simrad SM20 multi-beam hydroacoustic array. Shown are the observed mean and maximum horizontal distance, measured by GPS, between the survey vessel and the test tag for each of the sensors.

	<b>Distance (m) to Suspended Tag (Depth = ~17m)</b>			
	Mean	Std. Dev.	Maximum	n
Lotek Hydrophone (Tag Power $\geq$ 5)	58.8	39.6	189.2	289
Lotek Hydrophone (Tag Power $\geq$ 90)	29.5	19.9	70.7	35
SM20 Tag "Flash" Detected - Along.	12.0	7.7	30.7	30
SM20 Tag "Flash" Detected - Athwart.	42.4	7.2	55.2	7



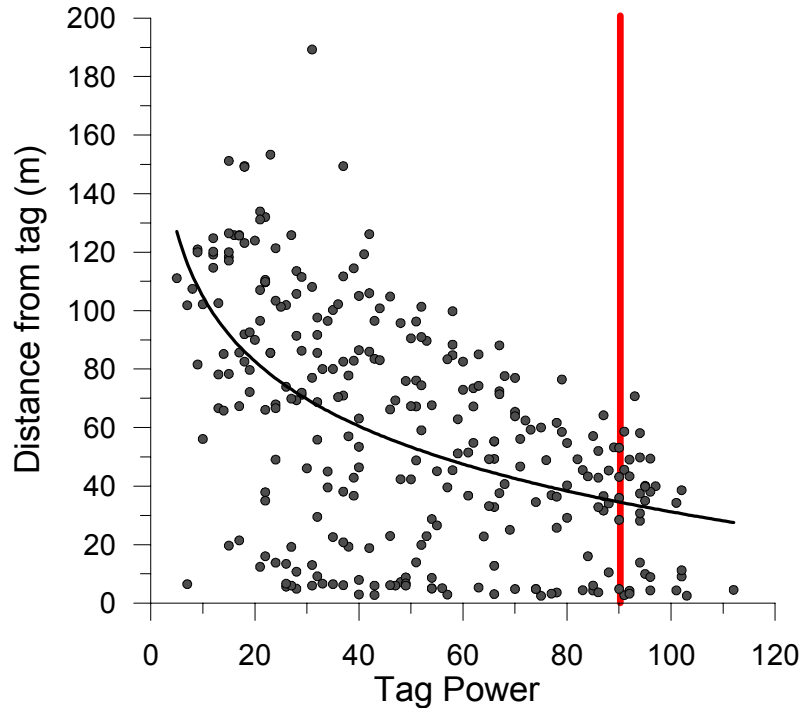


Figure 7: The observed relationship between the tag signal power (as reported by Lotek Maphost hydrophone software) and the distance of the survey vessel from the fixed tag position. The vertical line at tag power “90” indicates the minimum tag power threshold chosen for determining a lake trout position fix.

## Tag Detection Trials – SM20 Multi-beam Hydroacoustics

Results of the tag detection trials reveal that the tag signal or “flash” is detected by the SM20 multi-beam hydroacoustic array only when the survey vessel is relatively close to the fixed tag position and was dependent on the orientation of the swath relative to the tag position (figure 8). The maximum distance from the tag where a flash was detected was observed to be ~ 55 m when the tag was broadside (athwartship,  $\sim 120^\circ$ ) to the survey vessel and was ~ 31 m when the tag was along (alongship,  $20^\circ$ ) the vessel track (table 5). Infrequent “ghost flashes” or weak tag flashes that were not associated with a specific SM20 beam number were observed up to 100 m away and were likely caused by multi-path signals (bouncing from bottom or lake surface) from the tag.



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnetechnologies.ca](http://www.milnetechnologies.ca)

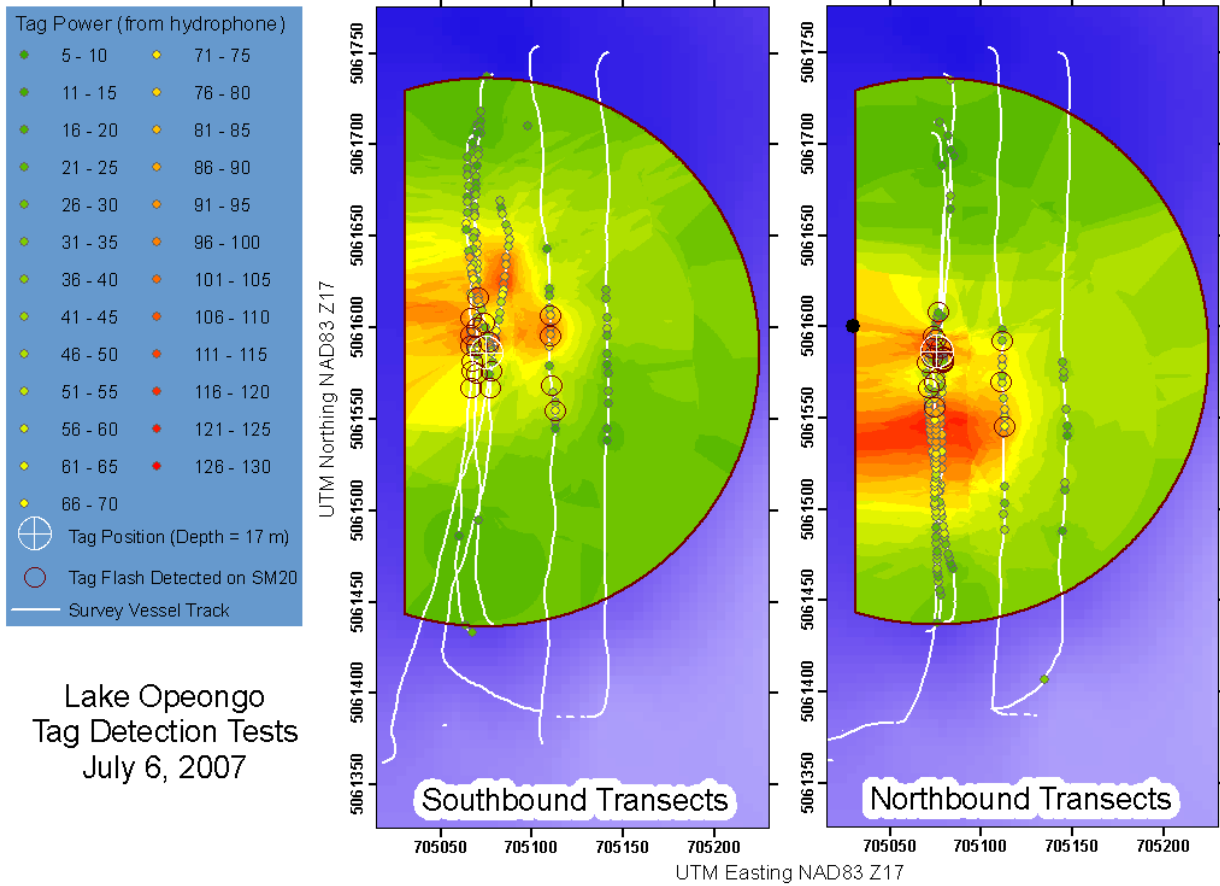


Figure 8: Shown are the vessel transects (northbound & southbound) completed to test the detectability of the Lotek MAP tags by the Lotek "Maphost" hydrophone hardware and the SM20 multibeam. Solid coloured circles are the observed tag signal "power" where dark green is < "10" and red is > "105". Open circles indicate the position where a tag "flash" was observed on the SM20 multi-beam display. (⊕) indicates the position of the test tag. Background shading is the interpolated tag "power" from the observed points (radial basis functions). Note the position of the tag detection "hot spot" is not centered on the fixed tag location but is dependent on the direction of travel relative to the tag position.

## Fish Tracking

Survey crews completed on average ~5.8 hours of lake trout tracking per day over 12 days for a total of >80 hours of tracking over the project July 4 – 17, 2007 (table 6). Throughout the survey period 14 tagged fish were detected while lake trout tag ID's 5 & 11 were never located (table 7). As these missing tags were not reported in the creel survey, it is likely they moved out of the survey area into the North or East Arms of the lake.



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

All of the tags that were detected with the hydrophone equipment were also detected by the SM20 multibeam at least once over the survey period. Of the 80 hours of available SM20 multi-beam survey data, a total of ~12 hours of the echogram segments include observations of tagged lake trout.

Table 6: Summary of the fish tracking survey effort and the number and total duration of events where the flash from a tagged lake trout was observed on the SM20 multibeam echogram. The percent of survey duration is proportion of the total duration of the SM20 events compared to the total "search time". \*Note that the "Survey & Search Duration" includes only those segments of the vessel track where crew was actively searching for tagged fish (i.e. excludes those segments south of Bates Island, calibration exercises, multi-frequency surveys, etc.).

Date	Survey & Search Duration (Hrs.)*	Number of SM20 Events	Total SM20 Events Duration (Hrs.)**	Percent of Survey Duration
July 4, 2007	10.86	22	0.48	4.4
July 5, 2007	5.65	7	0.53	9.4
July 6, 2007	5.96	7	0.39	6.6
July 7, 2007	6.88	30	1.31	19.0
July 8, 2007	3.49	4	0.09	2.7
July 9, 2007	3.91	7	0.30	7.6
July 10, 2007	1.98	2	0.40	20.3
July 11, 2007	9.39	12	2.85	30.4
July 12, 2007	0.47	<i>Calibrations &amp; Henley Engine Problems</i>		
July 13, 2007	5.32	<i>Multi-frequency Crep. Survey</i>		
July 14, 2007	4.35	6	0.56	12.9
July 15, 2007	9.18	7	1.67	18.2
July 16, 2007	10.69	20	2.74	25.7
July 17, 2007	2.09	7	0.38	18.4
<i>Sum:</i>	<i>80.22</i>	<i>131.00</i>	<i>11.71</i>	



Table 7: Summary of tagged lake trout sampling attributes and number of tag detections observed with the hydrophone receiver hardware. Also shown is the total number of incidences (or echogram regions) where acoustic backscatter (Sv) and single target detections (ST) from tagged lake trout were observed on the Simrad EK60 70 kHz or 120 kHz split-beam echogram.

Lake Trout Tagging Data				Hydrophone Detections		EK60 Lake Trout Detection Regions				
Lake Trout ID	Fork Tag Length (mm)	Round Weight (g)	Tagging Site	Tag Power >0	Tag Power >= 90	Total Number of Sv Regions	70 kHz Number of ST Regions	70 kHz Number of ST's (Beam Comp. <=6.0 dB)	120 kHz Number of ST Regions	120 kHz Number of ST's (Beam Comp. <=6.0 dB)
1	501	1450	Sunny Side	3407	984	40	17	286	27	145
2	699	3760	Sunny Side	1695	652	26	12	229	16	74
3	483	1400	Froggers Pt.	1998	544	9	5	101	5	29
4	542	2100	Froggers Pt.	2119	230	15	9	102	7	40
5	486	1400	Froggers Pt.				<i>Not Detected</i>			
6	848	8620	Windy Pt.	3420	604	64	23	152	38	85
7	448	1065	Windy Pt.	895	138					
8	484	1475	Windy Pt.	3050	891	21	13	165	13	50
9	596	2480	Finger Isld.N Arm Narrows	1106	104	2	0	0	0	0
10	616	2845	Finger Isld.N Arm Narrows	638	127	0	0	0	0	0
11	494	1256	Weather Stn. Isld.				<i>Not Detected</i>			
12	462	1140	Sunny Side	1524	371	3	2	27	1	5
13	430	915	Sunny Side	804	168	0	0	0	0	0
14	412	845	Sunny Side	866	345	18	8	60	8	19
15	538	1860	Frogger's Pt.	770	118	8	4	61	7	41
16	494	1650	Frogger's Pt.	2058	762	11	0	0	8	13
<i>Average:</i>	533	2141		<i>Sum:</i> 24350	6038	217	93	1183	130	501
<i>Min.:</i>	412	845								
<i>Max.:</i>	848	8620								



Table 8: Summary of the total number of incidences (or echogram regions) where acoustic backscatter (Sv) and single target detections (ST) from tagged lake trout were observed on the Simrad EK60 70 kHz or 120 kHz split-beam echogram by survey date and lake trout tag ID. The number of single targets (ST's) reported in this table were detected using a maximum beam compensation of 6.0 dB.

Date	Lake Trout Tag ID	Number of Sv Regions	70 kHz			120 kHz		
			Number of ST Regions	Number of ST's	Average Target Depth (m)	Number of ST Regions	Number of ST's	Average Target Depth (m)
July 5, 2007	3	1	n/a	n/a	-	0	0	-
July 6, 2007	6	17	n/a	n/a	-	7	11	17.9
	1	21	n/a	n/a	-	12	22	14.9
July 7, 2007	2	6	n/a	n/a	-	3	4	10.9
	6	11	n/a	n/a	-	6	8	13.7
	9	2	n/a	n/a	-	0	0	-
	16	11	n/a	n/a	-	8	13	13.5
July 8, 2007	3	1	n/a	n/a	-	1	12	13.5
	6	1	n/a	n/a	-	1	3	17.1
July 11, 2007	1	9	9	126	12.5	9	60	12.5
	8	14	10	152	16.5	10	43	16.1
	12	3	2	27	19.0	1	5	19.3
	14	1	1	13	12.1	1	3	12.1
July 14, 2007	2	5	4	28	9.8	4	12	9.7
	14	5	1	14	13.0	2	3	13.0
July 15, 2007	1	5	3	21	19.1	2	7	18.4
	14	12	6	33	11.3	5	13	11.4
	15	3	2	47	15.3	3	33	14.4
July 16, 2007	1	5	5	139	22.5	4	56	21.9
	3	7	5	101	10.1	4	17	10.0
	4	15	9	102	13.0	7	40	12.8
	6	30	21	124	18.6	21	53	18.8
	8	7	3	13	16.6	3	7	16.6
	15	5	2	14	12.7	4	8	12.7
July 17, 2007	2	15	8	201	12.7	9	58	12.8
	6	5	2	28	13.1	3	10	12.8
<i>Sum</i>		<i>217</i>	<i>93</i>	<i>1183</i>		<i>130</i>	<i>501</i>	



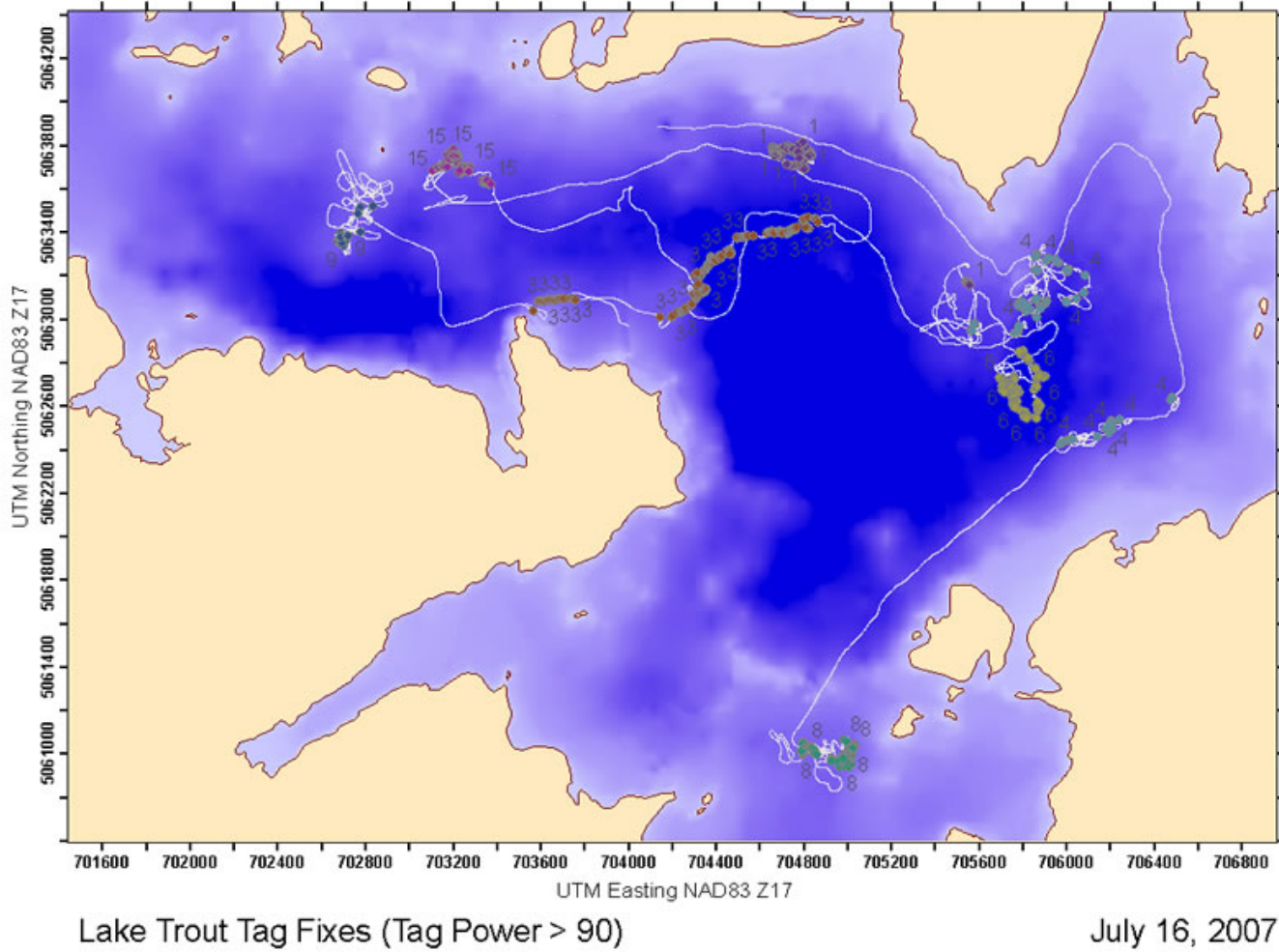


Figure 9: Map of the tagged lake trout position fixes (●) from tracking surveys completed on July 16, 2007 where tag power was  $\geq 90$ . Lake trout tag number is indicated beside each fix. The grey line denotes the survey vessel path.



## Lake Trout Interactions and Foraging Behaviour

Utilization of the SM20 multibeam technology for detecting tagged lake trout provided a unique opportunity to collect information about the ecological interactions between the lake trout and its prey or with other untagged “trout like” targets. SM20 echogram recordings, exceeding more than 2 hours of survey time, captured several examples of these interactions (table 9). Examples include >24 incidences of a tagged lake trout or an untagged “trout-like” target responding to, or associated with one or more lake herring schools observed within the display area of the SM20 multi-beam. Also observed was another 39 incidences where a tagged lake trout was associated with or was observed to directly respond to another large “trout-like” target and include what appears to be direct physical contact, rapid changes in swimming depth towards an observed target, or shoaling behaviour. Although no direct interactions were observed between two tagged fish, ~14 examples of tag “flashes” from two or more tagged lake trout flashing together within the detection limits of the multi-beam display were observed and may suggest some indirect interaction. Replays of a selection of those echograms where such interactions were observed are available for viewing at [http://www.milnettechnologies.ca/news.htm#Prelim\\_Results](http://www.milnettechnologies.ca/news.htm#Prelim_Results)

## Habitat Mapping

Preliminary lake bottom substrate classification was completed for a segment of the survey transects using Quester Tangents Impact classification software. Iterative analysis of the acoustic response through the bottom revealed 4 major substrate classes along the survey segment (figure 10 & 11). Inclusion of additional survey segments will likely reveal more complex habitat classes.



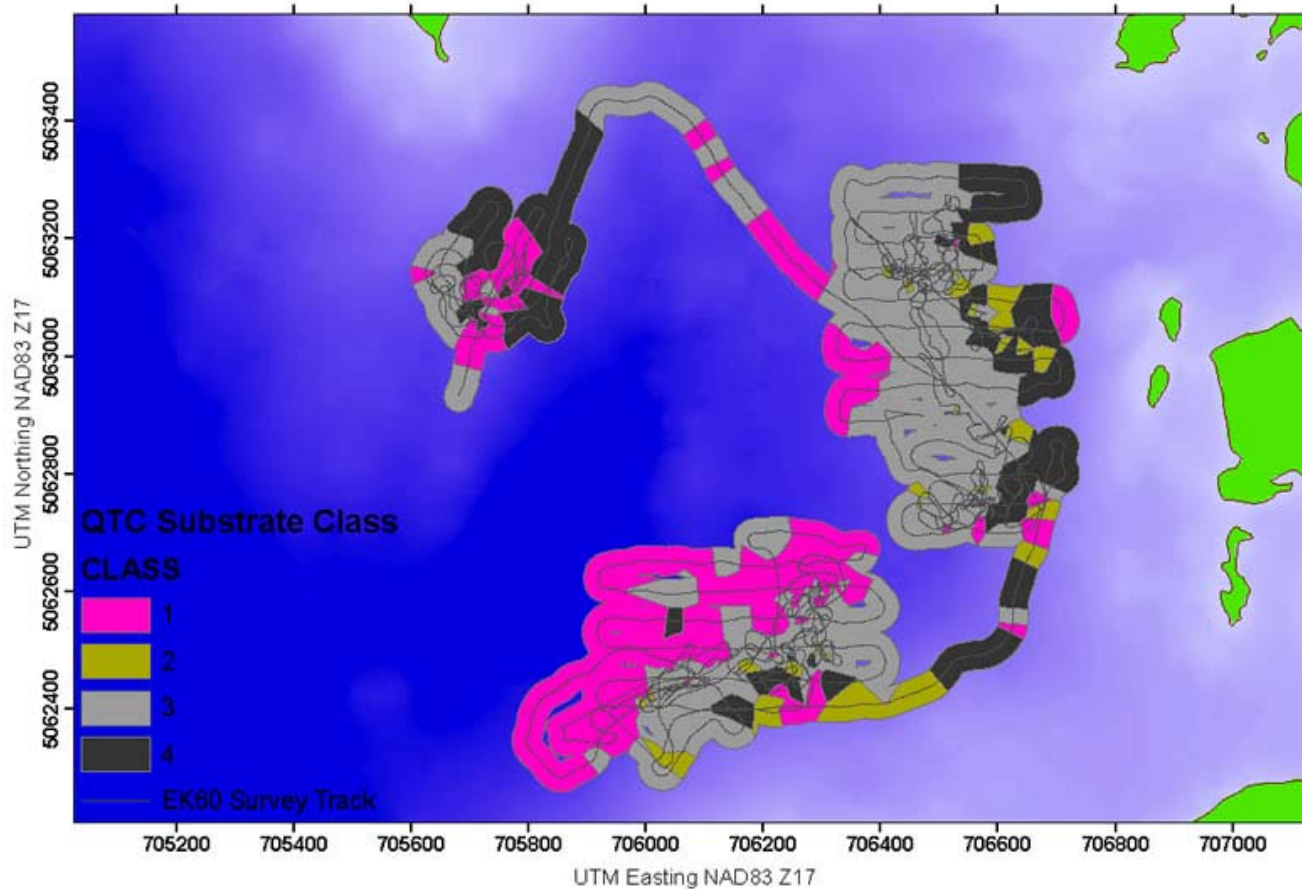
**Milne Technologies**

*Environmental & Aquatic Resource Consulting*  
[www.milnettechnologies.ca](http://www.milnettechnologies.ca)

Table 9: Summary of the total number of incidences (i.e. “events”) where tagged and untagged lake trout were observed to be: i. actively associated with a school (Direct Interaction - LT/School), ii. found closely associated to or directly interacting with other tagged or untagged “lake trout like” targets (Direct Interaction - LT/LT), iii. observed within the immediate area but no direct interactions observed (Indirect Interactions – LT/LT). “Simultaneous Pings” refers to those interactions where flashes from 2 or more tagged lake trout were observed to be flashing together within the detection limits of the SM20. Also shown is the observed total amount of time (in hours) of each type of interaction.

Interaction	Interaction Type	Total Number of Events	Interactions that include tagged fish	Interactions that include >=2 tagged fish	Total Event Duration (sec)
Direct Interaction	LT/School	16	7	1	1064
Direct Interaction	LT/LT & LT/School	8	6	0	891
Direct Interaction	LT/LT	30	24	0	2568
Direct Interaction	LT/LT & Simultaneous Pings	1	1	1	427
<b>Indirect Interaction</b>	LT/LT & Simultaneous Pings	14	14	14	2997
<i>Total Number of LT/School Direct Interactions:</i>		24	13		
<i>Total Number of LT/LT Direct Interactions:</i>		39	31		

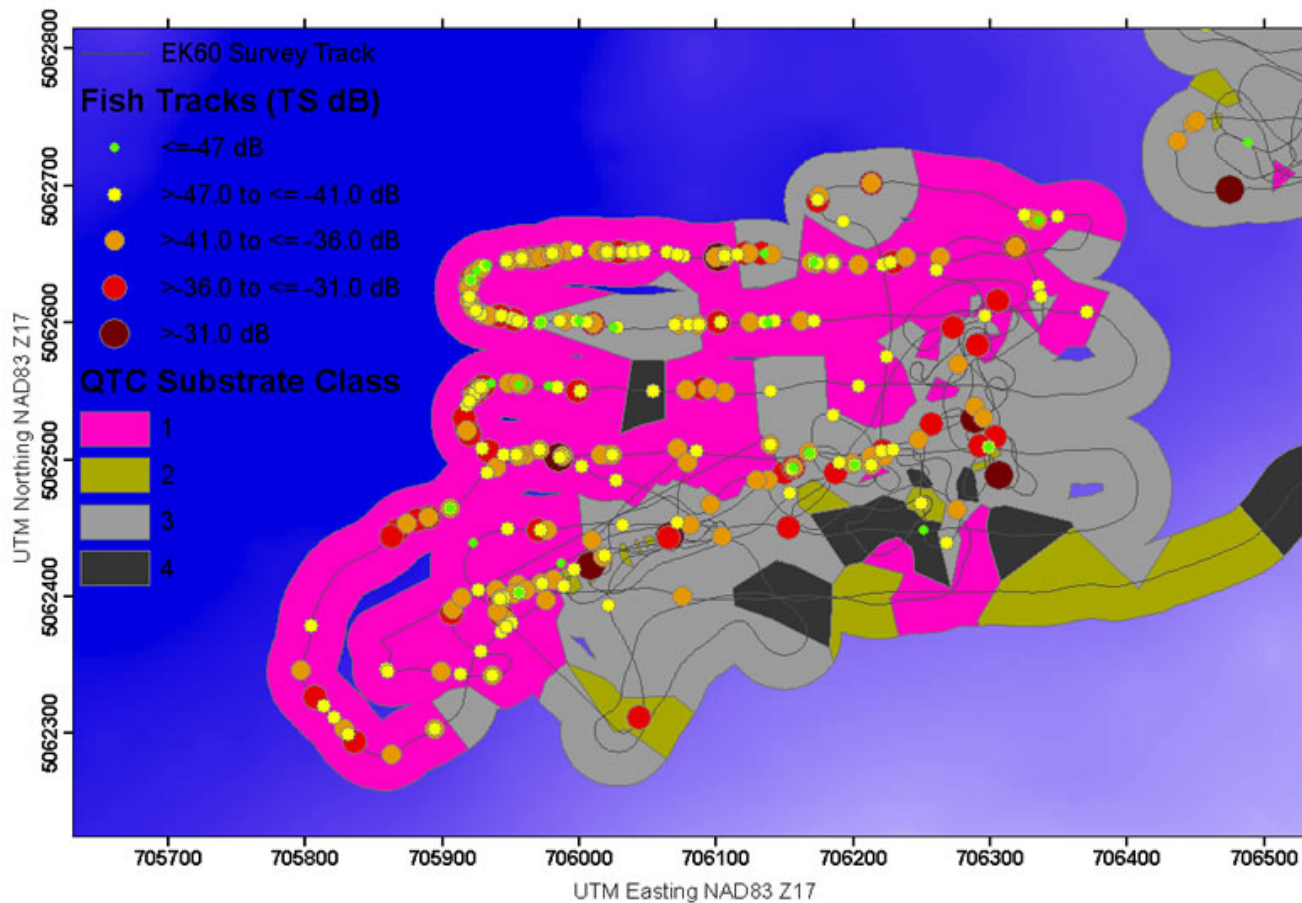




Lake Opeongo, Jones Bay - July 6, 2007  
QTC Substrate Classification, 4 Classes, EK60 120 kHz

Figure 10: QTC lake bottom substrate classification generated from the EK60 120 kHz single beam hydroacoustic bottom backscatter recorded on July 6, 2007 within Jones Bay. QTC substrate classes were interpolated over a buffer region that extends 25 m from the survey track using a Voronoi tessellation.





Lake Opeongo, Jones Bay - July 6, 2007  
QTC Substrate Classification, 4 Classes, EK60 120 kHz

Figure 11: QTC lake bottom substrate classification generated from EK60 120 kHz single beam hydroacoustic data. Data shown are a selection of the survey in southern Jones Bay, northeast of Englehart Island. QTC substrate classes were interpolated over a buffer region that extends 25 m from the survey track using a Voronoi tessellation. Also shown are the single target fish detections observed along the survey cruise track.



**Milne Technologies**

Environmental & Aquatic Resource Consulting  
[www.milnetechnologies.ca](http://www.milnetechnologies.ca)



# Milne Technologies

*Environmental and Aquatic Resource Consulting*  
**[www.milnetechnologies.ca](http://www.milnetechnologies.ca)**

28 Bradley Blvd. RR1 Hampton Ontario Canada L0B 1J0  
Tel: (416) 848-3948 [info@milnetechnologies.ca](mailto:info@milnetechnologies.ca)

Please contact Milne Technologies for the  
complete report.